

# NASA TECH BRIEF



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## Analysis of Filament Reinforced Metal-Shell Pressure Vessels

### The problem:

To develop a method to design a metal-lined filament-wound pressure vessel with filament winding patterns on the cylindrical portion and reinforced by circumferential windings for added strength.

### The solution:

This program has been developed to analyze design requirements and compute designs for metal-lined filament-wound pressure vessels with either geodesic (helical) or in-plane filament winding patterns on the cylindrical portion and over the ends, reinforced by circumferential windings on the cylindrical portion.

### How it's done:

The program establishes the optimum contours of the vessel ends, computes the filament and metal-liner stresses and strains at zero and design pressures, establishes the hoop-wrap thickness required for the cylindrical portion, and computes the weight, volume, and filament-path length for both the vessel components and the complete vessel. It also determines the stresses and strains in the filament and metal shells throughout service cycling on the basis of a series of pressure, composite-temperature, and metal-liner temperature inputs.

The program includes four functional parts for use in pressure vessel design and service cycle history analyses. Three parts are used to analyze design requirements and compute designs for complete pressure vessels. These include: solution of force equilibrium and strain compatibility equations at the equator of the heads, calculation of parameters describing head contours and the cylindrical section, and computation of rating properties of the entire vessel and its components. Inputs include various geometric parameters, metal shell and filament shell material properties, filament and longitudinal metal shell

stresses at winding conditions, and temperature design conditions. The program provides for seven optional variables of which four must be input: tensile hoop strain, tensile longitudinal strain and filament stress at design pressure; design pressure; metal shell thickness; filament shell thickness at the equator; and metal shell hoop stress at the winding conditions.

The program establishes the optimum head contour coordinates of the vessel's neutral axis, and inner and outer surfaces; computes the filament and metal shell stresses and strains at the winding and relaxed conditions, and at the design pressure and operating temperature conditions; establishes the metal and filament shell thicknesses; and computes the filament path length for the components and complete vessel. The vessel may be designed to specific conditions of pressure, and metal shell and composite temperatures. The stress and strain calculations for the design will be as established by these conditions. All information at zero internal pressure assumes room temperature; should zero-pressure information be required for other temperatures, the pressurization history analysis noted in Service Cycle History may be used.

In addition, the program optimizes the overall vessel design by designing the cylinder section to complement the head design; and it calculates the weights of the metal shell, filament shell, and entire vessel, calculates the surface area and contained volume, and calculates the vessel performance factor.

The fourth part of the program (Service Cycle History) is used to analyze stresses and strains in the filament and metal shells during the operating history of the vessel, through the input of a series of pressures, composite temperatures and metal-shell temperatures. It permits analysis of pressure and temperature cycles on the vessel, taking into account previous strains and loads.

(continued overleaf)

**Notes:**

1. This program is written in Fortran IV for use on the IBM-7094 computer.
2. The program is of interest to those working in structural design of vessels for aerospace projects as well as oceanographic work.
3. Inquiries concerning this innovation may be directed to:

COSMIC

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**Patent status:**

No patent action is contemplated by NASA.

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